

We claim:

1. A bonded abrasive tool, having a structure permeable to fluid flow, the tool comprising:

- 5 a) about 5-75 volume % sintered agglomerates, comprising a plurality of abrasive grains held with a binding material, the binding material being characterized by a melting temperature between 500 and 1400° C, and the sintered agglomerates having a three dimensional shape and an initial size distribution prior to manufacture of the tool;
- 10 b) a bond; and
- c) about 35-80 volume % total porosity, the porosity including at least 30 volume % interconnected porosity;

wherein at least 50 %, by weight, of the sintered agglomerates within the bonded abrasive tool retain a plurality of abrasive grains held in a three-dimensional

15 shape after manufacture of the tool.

2. The bonded abrasive tool of claim 1, wherein the sintered agglomerates have a loose packing density of ≤ 1.6 g/cc prior to manufacture of the tool.

20 3. The bonded abrasive tool of claim 2 wherein the bond is a vitrified bond.

4. The vitrified bonded abrasive tool of claim 3, wherein the tool comprises a bimodal porosity distribution of intra-agglomerate pores and interconnected porosity.

25 5. The bonded abrasive tool of claim 1, wherein at least 50%, by weight, of the sintered agglomerates have a size within the initial size distribution after manufacture of the tool.

30 6. The bonded abrasive tool of claim 1, wherein the binding material comprises a material selected from the group consisting essentially of ceramic

materials, vitrified materials, vitrified bond compositions and combinations thereof.

7. The bonded abrasive tool of claim 6, wherein the melting temperature of
5 the binding material is about 800 to 1,300° C.

8. The bonded abrasive tool of claim 6, wherein the binding material is a
vitrified bond composition comprising a fired oxide composition of 71 wt% SiO₂
and B₂O₃, 14 wt% Al₂O₃, less than 0.5 wt% alkaline earth oxides and 13 wt%
10 alkali oxides.

9. The bonded abrasive tool of claim 5, wherein the binding material is a
ceramic material selected from silica, alkali, alkaline-earth, mixed alkali and
alkaline-earth silicates, aluminum silicates, zirconium silicates, hydrated silicates,
15 aluminates, oxides, nitrides, oxynitrides, carbides, oxycarbides and combinations
and derivatives thereof.

10. The bonded abrasive tool of claim 1, wherein the interconnected porosity
is obtained without the use of pore inducing media during manufacture of the
20 tool.

11. The bonded abrasive tool of claim 1, wherein the bonded abrasive tool
has a maximum density of 2.2 g/cc.

25 12. The bonded abrasive tool of claim 1, wherein the interconnected porosity
of the tool is characterized by a relative air permeability value (Q/P) in
cc/second/inch of water at least 10% higher than the Q/P of a comparable
bonded abrasive tool made without the sintered agglomerates.

13. The bonded abrasive tool of claim 1, wherein the sintered agglomerates have an average size dimension two to twenty times larger than the average size of the abrasive grain.

5 14. The bonded abrasive tool of claim 13, wherein the initial size range of the sintered agglomerates is 200 to 3,000 micrometers in average diameter.

15. The bonded abrasive tool of claim 13, wherein the abrasive grains are microabrasive grains and the initial size range of the sintered agglomerates are 5
10 to 180 micrometers in average diameter.

16. The bonded abrasive tool of claim 1, wherein the average diameter of the sintered agglomerates is no greater than an average dimension of the interconnected porosity when the interconnected porosity is measured at a point
15 of a maximum opening.

17. The bonded abrasive tool of claim 2, wherein the tool comprises 35 to 52 vol % sintered agglomerates, 3 to 13 vol % vitrified bond and 35 to 70 vol % porosity.

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18 The bonded abrasive tool of claim 17, wherein the bond is selected from the group consisting of organic bonds and metal bonds.

19. The bonded abrasive tool of claim 1, wherein the tool further comprises at
25 least one component selected from the group consisting of secondary abrasive grain, filler materials, grinding aids, pore inducing media and combinations thereof.

20. A vitrified bonded abrasive tool, having a structure permeable to fluid flow,
30 the tool comprising:

a) about 5-75 volume % sintered agglomerates of a plurality of abrasive grain with a binding material, the binding material being characterized by a viscosity A at the binding material melting temperature;

b) a vitrified bond characterized by a viscosity B at the binding material melting temperature, viscosity B being at least 33 % lower than viscosity A; and

c) about 35-80 volume % porosity , including at least 30 volume % interconnected porosity.

21. The vitrified bonded abrasive tool of claim 20, wherein the viscosity A of the binding material is 345 to 55,300 poise at 1180° C.

22. The vitrified bonded abrasive tool of claim 20, wherein the viscosity B of the vitrified bond material is 30 to 37,000 poise at 1180° C.

23. The vitrified bonded abrasive tool of claim 20, wherein the sintered agglomerates have an initial three-dimensional shape and an initial size distribution, and, after manufacturing the tool with the sintered agglomerates, at least 50 %, by weight, of the sintered agglomerates within the tool retain a plurality of abrasive grains held in a three-dimensional shape, and at least 50%, by weight, of the sintered agglomerates have a size within the initial size distribution.

24. The bonded abrasive tool of claim 20 wherein the tool has a maximum density of 2.2 g/cc.

25. The bonded abrasive tool of claim 20, wherein the binding material comprises a material selected from the group consisting essentially of ceramic materials, vitrified materials, vitrified bond compositions and combinations thereof.

26. The bonded abrasive tool of claim 20, wherein the melting temperature of the binding material is 800 to 1,300° C.

27. The bonded abrasive tool of claim 20, wherein the interconnected porosity
5 is obtained without the use of pore inducing media during manufacture of the tool.

28. The bonded abrasive tool of claim 20, wherein the interconnected porosity of the tool is characterized by a relative air permeability value (Q/P) in
10 cc/second/inch of water at least 10% higher than the Q/P of a comparable bonded abrasive tool made without the sintered agglomerates.

29. The bonded abrasive tool of claim 20, wherein the sintered agglomerates have a an initial loose packing density of ≤ 1.6 g/cc prior to manufacture of the
15 tool.

30. A vitrified bonded abrasive tool, having a structure permeable to fluid flow, the tool comprising:

a) about 5-60 volume % sintered agglomerates of a plurality of abrasive grain with a binding material, the binding material being characterized by a
20 melting temperature A;

b) a vitrified bond characterized by a melting temperature B, melting temperature B being at least 150° C lower than melting temperature A; and

c) about 35-80 volume % porosity, including at least 30 volume % interconnected porosity.

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31. The vitrified bonded abrasive tool of claim 30, wherein the sintered agglomerates have an initial three-dimensional shape and an initial size distribution, and, after manufacturing the tool with the sintered agglomerates, at least 50 %, by weight, of the sintered agglomerates within the tool retain a
30 plurality of abrasive grains held in a three-dimensional shape, and at least 50%,

by weight, of the sintered agglomerates have a size within the initial size distribution.

32. The bonded abrasive tool of claim 30 wherein the tool has a maximum
5 density of 2.2 g/cc.

33. The bonded abrasive tool of claim 30, wherein the binding material
comprises a material selected from the group consisting essentially of ceramic
materials, vitrified materials, vitrified bond compositions and combinations
10 thereof.

34. The bonded abrasive tool of claim 30, wherein the melting temperature A
of the binding material is 950 to 1,300° C.

15 35. The bonded abrasive tool of claim 30, wherein the interconnected porosity
is obtained without the use of pore inducing media during manufacture of the
tool.

36. The bonded abrasive tool of claim 30, wherein the interconnected porosity
20 of the tool is characterized by a relative air permeability value (Q/P) in
cc/second/inch of water at least 10% higher than the Q/P of a comparable
bonded abrasive tool made without the sintered agglomerates.

37. The bonded abrasive tool of claim 20, wherein the sintered agglomerates
25 have a an initial loose packing density of ≤ 1.6 g/cc, prior to manufacture of the
tool.

38. A bonded abrasive tool, having a structure permeable to fluid flow, the tool
comprising:
30 a) about 34-56 volume % abrasive grain;
b) about 3-25 volume % bond; and

- c) about 35-80 volume % total porosity, including at least 30 volume % interconnected porosity;
wherein the interconnected porosity has been created without the addition of porosity inducing media and without the addition of elongated shaped materials
5 having a length to cross-sectional width aspect ratio of at least 5:1.

39. The bonded abrasive tool of claim 38, wherein 5-100 volume % of the abrasive grain consists of abrasive grain held within three-dimensional sintered agglomerates, and the sintered agglomerates comprise a plurality of abrasive
10 grains with a binding material, the binding material being characterized by a melting temperature between 500 and 1400° C.

40. The bonded abrasive tool of claim 38 wherein the bond is a vitrified bond.

15 41. The bonded abrasive tool of claim 39, wherein the binding material comprises a material selected from the group consisting essentially of ceramic materials, vitrified materials, vitrified bond compositions and combinations thereof.

20 42. The bonded abrasive tool of claim 38, wherein the interconnected porosity of the tool is characterized by a relative air permeability value (Q/P) in cc/second/inch of water at least 10% higher than the Q/P of a comparable bonded abrasive tool made without the sintered agglomerates.

25 43. The bonded abrasive tool of claim 39, wherein, the sintered agglomerates having a loose packing density of ≤ 1.6 g/cc prior to manufacture of the tool.

44. The bonded abrasive tool of claim 39, wherein the bonded abrasive tool has a bimodal porosity distribution of intra-agglomerate pores and
30 interconnected porosity.

45. The bonded abrasive tool of claim 39, wherein the tool further comprises at least one component selected from the group consisting of secondary abrasive grain, filler materials, grinding aids and combinations thereof.

5 46. The bonded abrasive tool of claim 39, wherein initial size range of the sintered agglomerates is 200 to 3,000 micrometers in average diameter.

47. The bonded abrasive tool of claim 39, wherein the abrasive grains are microabrasive grains and the initial size range of the sintered agglomerates is 5
10 to 180 micrometers in average diameter.

48. The bonded abrasive tool of claim 39, wherein the average diameter of the sintered agglomerates is no greater than an average dimension of the interconnected porosity when the interconnected porosity is measured at a point
15 of a maximum opening.

49. The bonded abrasive tool of claim 40, wherein the tool has a maximum density of 2.2 g/cc.

20 50. An abrasive tool comprising 5 to 75 volume % abrasive grain agglomerates, made by a method comprising the steps:

- a) feeding abrasive grain and a binding material, selected from the group consisting essentially of vitrified bond materials, vitrified materials, ceramic materials, inorganic binders, organic binders and combinations thereof, into a
25 rotary calcination kiln at a controlled feed rate;
- b) rotating the kiln at a controlled speed;
- c) heating the mixture at a heating rate determined by the feed rate and the speed of the kiln to temperatures from about 145 to 1,300° C,
- d) tumbling the mixture in the kiln until the binding material adheres to the
30 grain and a plurality of grains adhere together to create a plurality of sintered agglomerates;

e) recovering the sintered agglomerates from the kiln, the sintered agglomerates consisting of a plurality of abrasive grains bonded together by the binding material and having an initial three-dimensional shape and a loose packing density of ≤ 1.6 g/cc;

- 5 f) molding the sintered agglomerates into a shaped composite body; and
 g) thermally treating the shaped composite body to form the abrasive tool.

51. The abrasive tool of claim 50, further including the step of mixing the sintered agglomerates with a bond material to form an agglomerate mixture.

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52. The bonded abrasive tool of claim 51, wherein the bond material is a vitrified bond material.

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53. The vitrified bonded abrasive tool of claim 52, wherein the vitrified bond has a bond firing temperature at least 150° C lower than the binding material melting temperature.

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54. The bonded abrasive tool of claim 50, wherein the binding material comprises a material selected from the group consisting essentially of ceramic materials, vitrified materials, vitrified bond compositions and combinations thereof.

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55. The bonded abrasive tool of claim 54, wherein the melting temperature of the binding material is about 800 to 1,300° C.

56. The bonded abrasive tool of claim 55, wherein the binding material is characterized by a viscosity of about 30 to 55,300 poise at the melting temperature of the binding material.

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57. The bonded abrasive tool of claim 55, wherein the binding material is a vitrified bond composition comprising a fired oxide composition of 71 wt% SiO₂

and B_2O_3 , 14 wt% Al_2O_3 , less than 0.5 wt% alkaline earth oxides and 13 wt% alkali oxides.

58. The bonded abrasive tool of claim 54, wherein the binding material is a ceramic material selected from silica, alkali, alkaline-earth, mixed alkali and alkaline-earth silicates, aluminum silicates, zirconium silicates, hydrated silicates, aluminates, oxides, nitrides, oxynitrides, carbides, oxycarbides and combinations and derivatives thereof.

59. The bonded abrasive tool of claim 50, wherein the interconnected porosity is obtained without the addition of pore inducing media.

60. The bonded abrasive tool of claim 50, wherein the tool further comprises about 35-80 volume % total porosity, including at least 30 volume % interconnected porosity.

61. The bonded abrasive tool of claim 52, wherein the tool has a maximum density of 2.2 g/cc.

62. The bonded abrasive tool of claim 50, wherein the sintered agglomerates have an average size dimension two to twenty times larger than the average size of the abrasive grain.

63. The bonded abrasive tool of claim 50, wherein the initial size range of the sintered agglomerates is 200 to 3,000 micrometers in average diameter.

64. The bonded abrasive tool of claim 50, wherein the abrasive grains are microabrasive grains and the initial size range of the sintered agglomerates is 5 to 180 micrometers in average diameter.

65. The bonded abrasive tool of claim 60, wherein the interconnected porosity of the tool is characterized by a relative air permeability value (Q/P) in cc/second/inch of water at least 10% higher than the Q/P of a comparable bonded abrasive tool made without the sintered agglomerates.

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66. The bonded abrasive tool of claim 51, wherein the tool comprises 35 to 52 vol % sintered agglomerates, 3 to 13 vol % vitrified bond and 35 to 70 vol % porosity.

10 67. The bonded abrasive tool of claim 50, wherein the tool further comprises at least one component selected from the group consisting of secondary abrasive grain, filler materials, grinding aids, pore inducing media and combinations thereof.

15 68. A method of grinding, comprising the steps of:

a) providing a bonded abrasive tool, having a structure permeable to fluid flow, the tool comprising:

1) 5 to 75 volume % sintered agglomerates comprising a plurality of abrasive grains held with a binder material, the binder material being characterized by a melting temperature between 500 and 1400° C, and the sintered agglomerates having a three dimensional shape and having an initial size distribution prior to manufacture of the tool;

2) a bond; and

3) about 35-80 volume % total porosity, including at least 30 volume % interconnected porosity;

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wherein at least 50 %, by weight, of the sintered agglomerates within the bonded abrasive tool retain a plurality of abrasive grains held in a three-dimensional shape after manufacture of the tool;

b) bringing the bonded abrasive tool into contact with a workpiece; and

30 c) abrading the surface of the workpiece with the bonded abrasive tool.

69. A method of grinding, comprising the steps of:

a) providing a bonded abrasive tool, having a structure permeable to fluid flow, the tool comprising:

- 5 1) about 34-56 volume % abrasive grain;
- 2) about 3-25 volume % bond; and
- 3) about 35-80 volume % total porosity, including at least 30 volume % interconnected porosity; wherein the interconnected porosity has been created without the addition of porosity inducing filler material and without
- 10 the addition of elongated shaped materials having an aspect ratio of at least 5:1;
- b) bringing the bonded abrasive tool into contact with a workpiece; and
- c) abrading the surface of the workpiece with the bonded abrasive tool.

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70. A method of agglomerating abrasive grain, comprising the steps:

a) feeding the grain and a binding material, selected from the group consisting essentially of vitrified bond materials, vitrified materials, ceramic materials, inorganic binders, organic binders, water, solvent and combinations thereof, into a rotary calcination kiln at a controlled feed rate;

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b) rotating the kiln at a controlled speed;

c) heating the mixture at a heating rate determined by the feed rate and the speed of the kiln to temperatures from about 145 to 1,300° C,

d) tumbling the grain and the binding material in the kiln until the binding material adheres to the grain and a plurality of grains adhere together to create a plurality of sintered agglomerates; and

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e) recovering the sintered agglomerates from the kiln, whereby the sintered agglomerates have an initial three-dimensional shape, a loose packing density of ≤ 1.6 g/cc and comprise a plurality of abrasive grains.

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71. The method of claim 70, further comprising the step of making a uniform mixture of the abrasive grain and the binding material and then feeding the mixture into the rotary calcination kiln.

5 72. The method of claim 70, wherein the mixture is tumbled in the heating kiln for about 0.25 to 2.0 hours.

73. The method of claim 70, wherein the sintered agglomerates are two to twenty times larger in size than the abrasive grain.

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74. The method of claim 70, wherein the kiln is tilted to an angle of incline of about 0.5 to 5 degrees.

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75. The method of claim 70, wherein the kiln is rotated at a speed of 0.5 to 10 rpms.

76. The method of claim 71, wherein the mixture is fed into the kiln at a feed rate of about 5 to 910 Kg/hr.

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77. The method of claim 71, wherein the mixture feed rate is set such that the mixture occupies 8-12 volume % of the kiln volume.

78. The method of claim 70, wherein the sintered agglomerates have a minimum crush strength of 0.5 at 50% crush fraction in a compaction test.

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79. The method of claim 71, wherein the mixture further comprises at least one component selected from the group consisting of secondary abrasive grain, filler materials, grinding aids, pore inducing media and combinations thereof.

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80. The method of claim 71, wherein the mixture further comprises pore inducing media selected from the group consisting of hollow glass spheres,

ground walnut shells, hollow spheres or beads of plastic material or organic compounds, foamed glass particles, bubble mullite and bubble alumina, and combinations thereof.

5 81. The method of claim 70, wherein the grain and the binding material are heated to a temperature of 800-1200° C in the kiln.

82. The method of claim 81, wherein the temperature is effective to cause the binding material to melt and flow and the viscosity of the melted binding material
10 is at least 300 poise.

83. The method of claim 71, wherein the uniform mixture is agglomerated to form green agglomerates and then the green agglomerates are fed into the rotary calcination kiln.

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84. Sintered agglomerates of abrasive grain, made by a method comprising the steps:

a) feeding abrasive grain with a binding material into a rotary calcination kiln at a controlled feed rate;

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b) rotating the kiln at a controlled speed;

c) heating the mixture at a heating rate determined by the feed rate and the speed of the kiln to temperatures from about 145 to 1,300° C,

d) tumbling the grain and the binding material in the kiln until the binding material adheres to the grain and a plurality of grains adhere together to create a
25 plurality of sintered agglomerates; and

e) recovering the sintered agglomerates from the kiln,
whereby the sintered agglomerates have an initial three-dimensional shape, a loose packing density of ≤ 1.6 g/cc and contain a plurality of abrasive grains.

85. The sintered agglomerates of claim 84, further comprising at least one component selected from the group consisting of secondary abrasive grain, filler materials, grinding aids, pore inducing media and combinations thereof.
- 5 86. The sintered agglomerates of claim 84, wherein the binding material comprises a material selected from the group consisting essentially of selected from the group consisting essentially of vitrified bond materials, vitrified materials, ceramic materials, inorganic binders, organic binders, organic bond materials, metal bond materials and combinations thereof.
- 10 87. The sintered agglomerates of claim 84, further comprising the step of making a uniform mixture of the abrasive grain and the binding material and then feeding the mixture into the rotary calcination kiln.
- 15 88. The sintered agglomerates of claim 84, wherein the sintered agglomerates have an average size dimension two to twenty times larger than the average size of the abrasive grain.
- 20 89. The sintered agglomerates of claim 84, wherein the initial size range of the sintered agglomerates is 200 to 3,000 micrometers in average diameter.
- 25 90. The sintered agglomerates of claim 84, wherein the abrasive grains are microabrasive grains and the initial size range of the sintered agglomerates is 5 to 180 micrometers in average diameter.
91. The sintered agglomerates of claim 84, wherein the granule comprises about 30-88 volume % porosity.
- 30 92. The sintered agglomerates of claim 91, wherein up to 75 volume % of the porosity comprises interconnected porosity.

93. The sintered agglomerates of claim 84, wherein the relative density of the agglomerates, as measured by a fluid displacement volume technique and expressed as a ratio of the volume of the agglomerates to the apparent volume of the abrasive grain and the binder material used to make the agglomerates, is
- 5 a maximum of 0.7.